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Original Communication

# Study of the normal internal organ weights in Tehran's population

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ABSTRACT

*Objective:* Examine the normal adult internal organ weight and its relationship with body height, body weight, body mass index and age.
*Materials and methods:* Prospective analysis of data from 1222 autopsies in Legal Medicine Organization of Iran from 1st January, 2007 to 1st September, 2008. All the subjects were adult residents of Tehran died from external causes and showed no pathological changes.
*Results:* The weight of the brain, heart, lungs, liver, spleen, pancreas, kidneys, thyroid gland, the pituitary gland, the suprarenal glands, testes, prostate, ovaries and the uterus were collected from 914 males and 308 females between 15 and 88 years. The weight of all the organs was correlated statistically with at least one external parameter with the exception of the pancreas in men, the uterus, the spleen and the thyroid in women. Organ weights decreased with age except for the heart and the prostate, and increased in relation to body height and/or BMI. Except for the brain, the organ weight showed a better statistical correlation with the BMI than the body height.
*Conclusion:* These results can be used as standard organ weights to determine abnormal evidences in Forensic and Pathologic corpses. However such results have to be regularly updated by pathologists in order to keep organ weight as a good criterion used in postmortem diagnosis.


## 1. Introduction

The human body organ weight is one of the criteria regularly used by pathologists during an autopsy to detect what is pathological. Human body organs play a significant role in almost all branches of medical sciences including forensic science, as any deviation in weight from the normal range suggests some pathological change in the organ and thus helps in interpreting the opinion regarding the cause of death in various pathological conditions and also in finding out the relationship between trauma and disease.[1–4]

Organ weight also plays a significant role in estimation of body height and weight of an individual.[1–3] Human organ weights besides race, age, gender, etc. are also anticipated to be dependent on environmental and socioeconomic conditions which may be quite different in various parts of the world. Hence, the organ weights reported from other parts of the world are definitely not applicable directly to the population of elsewhere. As literature available on the subject for the population of Iran in general and Tehran in particular is scanty, hence the present study is an attempt to provide such information.

## 2. Materials and methods

### 2.1. Study design

Prospective analysis of deaths due to various medico-legal causes was done.

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### 2.2. Setting and population

The study was conducted within the framework of the Tehran's Legal Medicine Organization (LMO), the largest Iran's LMO that serves about 20% of the Iran's population. The population of the Tehran city in the center of Iran is about 8,000,000, most from middle to high socioeconomic level.[5,6] The LMO investigates all unnatural and suspicious deaths and does more than 10,000 autopsies annually.[7–9]

We analyzed 1222 (914 males and 308 females) adult subjects who died between 1st January, 2007 and 1st September, 2008 and referred to LMO for various medico-legal causes. Postmortem examination was conducted by the department of Forensic Medicine within maximum 6 h of death. Items of age, sex, nationality, residence, the weight and height of the body as well as the organ weights were collected from postmortem records. All selected subjects were Iranian residents of Tehran who died of injury with short survival time (<6 h) and all those who showed any macroscopic evidence of disease or histological abnormalities were excluded.

The weight and the height of the body were measured by the forensic pathologist responsible for the autopsy. The body height measured the head-to-heel length. All the bodies were weighed naked with the same weighing machine (300 kg range, 100 g intervals). As the delay between death and autopsy can alter organ weights, all necropsies were performed by forensic pathologists within 6 h after death. Standard autopsy protocol and procedure (as described in Current methods of Autopsy Practice by Ludwig, 2nd edition, W.B. Saunders Company) were employed for removal of various organs.[10] After removing the extraneous tissues and draining the blood, each organ was weighed on electronic weighing machine having the accuracy of ±0.1 g. The electronic weighing machines being used were of the same type (3000 g range, 0.1 g intervals). They were daily calibrated before the beginning of autopsy with a reference weight of 1 kg. They were reset before each weighing during autopsy.

The weighed organs included the brain, the heart (with epicardial fat), the right and the left lung, the liver, the spleen, the pancreas, the right and the left kidney, the right and the left suprarenal gland, the right and the left testis, the prostate gland, the right and the left ovary, the uterus, the hypophysis and the thyroid gland. Except for the brain and the heart, the organs were weighed before being dissected and cut open. Hearts were weighed after being dissected and washed to remove clotted blood from the chambers. The organ weights were carefully recorded after each autopsy in accordance with the European Recommendation on the harmonization of medico-legal autopsy rules.[11]

### 2.3. Data collection

All adult cases dying from injury with no macroscopic evidence of disease or histological abnormalities were selected. Subjects with septicemia or gross organ pathology were not included in the present study. We excluded all subjects that their delay between death and autopsy was more than 6 h.

**Table 2**
BMI subgroups for both males and females.

| BMI (kg m$^{-2}$) | | | | | | |
|---|---|---|---|---|---|---|
| Gender | Males | | | Females | | |
| | 14–20 | 21–25 | 26–39 | 17–20 | 21–25 | 26–39 |
| Mean (kg m$^{-2}$) | 18.5 | 23.4 | 28.4 | 19.1 | 23.3 | 30.7 |
| S.D. | 1.3 | 1.1 | 2.3 | 1.3 | 1.2 | 3.3 |
| *n* | 52 | 541 | 321 | 15 | 152 | 141 |

### 2.4. Ethical considerations

Written informed consent was obtained from the bereaved family of every deceased prior to the autopsy examination.

### 2.5. Data analysis

In analysis and interpretation of data, we use a model published by Grandmaison et al. formerly.[12] Three height and BMI subgroups were defined for both males and females (see Tables 1 and 2). The BMI was calculated using the formula[13]:

$$\text{BMI} = \text{Body weight (kg)}/\text{Height}^2(\text{m}^2)$$

Each subgroup was defined so as to correspond to subdivisions of the population with a number strong enough to be statistically representative of variations in inter-individual morphology. The mean and standard deviation (S.D.) of organ weight has been determined for each subgroup. Correlations between organ weights and body height, BMI and age, respectively, were studied by performing Pearson Correlation. We classified the strength of the correlation between organ weight and the parameters in three categories: strong significant ($P < 0.01$), weak but significant ($0.01 \leqslant P \leqslant 0.05$) and not significant ($P > 0.05$). Data analysis was performed by using SPSS 16 software.

## 3. Results

The external parameters being considered were the age, the height, the body weight and the BMI of the deceased. The corresponding values are shown in Table 3. All these parameters fitted to a Gaussian distribution curve except for the age, which showed that the majority of the individuals in the sample were less than 50 years old.

**Table 3**
External parameters for males and females.

| External parameters | | | | |
|---|---|---|---|---|
| Gender | Males ($n$ = 914) | | Females ($n$ = 308) | |
| | Mean | S.D. | Mean | S.D. |
| Age (years) | 43.4 | 17.8 | 45.2 | 22.2 |
| Height (cm) | 170.8 | 18.0 | 157.9 | 17.6 |
| Body weight (kg) | 74.2 | 10.8 | 65.7 | 13.2 |
| BMI (kg m$^{-2}$) | 24.8 | 3.1 | 26.1 | 4.5 |

**Table 1**
Height subgroups for both males and females.

| Height (cm) | | | | | | |
|---|---|---|---|---|---|---|
| Gender | Males | | | Females | | |
| | 151–165 | 166–175 | 176–192 | 141–155 | 156–165 | 166–175 |
| Mean (cm) | 162.7 | 171.3 | 179.8 | 152.4 | 162.0 | 168.4 |
| S.D. | 3.4 | 2.6 | 3.1 | 3.6 | 2.6 | 2.7 |
| *n* | 99 | 579 | 236 | 73 | 205 | 30 |

**Table 4**
The mean, standard deviation and range of the organs weight (g) of the studied population (males and females).

| Organ weight (g) | | | | |
|---|---|---|---|---|
| Gender | Males ($n$ = 914) | | Females ($n$ = 308) | |
| | Mean ± S.D. | Range | Mean ± S.D. | Range |
| Brain | 1322.3 ± 116.8 | 980–1704 | 1208.9 ± 131.1 | 885–1697 |
| Heart | 359.9 ± 76.6 | 209–607 | 319.2 ± 86.4 | 199–540 |
| Right lung | 567.8 ± 175.7 | 327–912 | 442.1 ± 118.8 | 305–727 |
| Left lung | 533.8 ± 197.7 | 302–876 | 417.3 ± 106.9 | 303–670 |
| Liver | 1501.6 ± 298.2 | 917–1881 | 1372.2 ± 297.6 | 895–1572 |
| Spleen | 172.1 ± 69.1 | 97–255 | 166.5 ± 68.0 | 92–222 |
| Pancreas | 88.0 ± 24.7 | 63–164 | 80.4 ± 23.0 | 63–139 |
| Right kidney | 147.9 ± 48.8 | 108–215 | 130.9 ± 25.5 | 107–196 |
| Left kidney | 150.3 ± 52.1 | 115–228 | 135.3 ± 26.2 | 112–220 |
| Thyroid | 22.2 ± 7.0 | 11–40 | 17.5 ± 4.9 | 11–31 |
| Right suprarenal | 10.3 ± 4.5 | 5–26 | 10.4 ± 4.3 | 5–24 |
| Left suprarenal | 10.4 ± 4.5 | 5–27 | 10.5 ± 4.2 | 5–30 |
| Hypophysis | 0.7 ± 0.2 | 0.3–1.3 | 0.6 ± 0.2 | 0.2–1.0 |
| Right testis | 24.7 ± 5.8 | 12–60 | – | – |
| Left testis | 25.4 ± 6.4 | 14–70 | – | – |
| Prostate | 34.6 ± 13.1 | 13–73 | – | – |
| Right ovary | – | – | 16.4 ± 7.6 | 10–34 |
| Left ovary | – | – | 16.9 ± 6.5 | 10–33 |
| Uterus | – | – | 61.1 ± 28.2 | 27–120 |

The mean, the standard deviation and the range of the organ weight of the studied population are shown in Table 4.

The mean and the standard deviation of the organ weight corresponding to each subgroup of height are shown in Table 5. The same data but corresponding to each subgroup of BMI is shown in Table 6.

The correlation ($P$ values) of organ weights with height, BMI and age for males and females are shown in Table 7.

The weight of all the organs was correlated statistically with at least one external parameter with the exception of the pancreas in men, the uterus, the spleen and the thyroid in women which could not be correlated with any parameters.

When there was correlation, the organ weight increased with BMI and/or body height. In general, the organ weight was more correlated with BMI than body height.

For men, the heart, the liver, the thyroid, the hypophysis and the testicles weights were strongly and positively correlated with the BMI. The correlation was weak but significant for the lungs and the kidneys. There was no significant correlation for the other organs with BMI in men. For women, the heart, the liver and the pancreas weights were strongly correlated with the BMI. The correlation was weak but significant for the kidneys and the ovaries. No correlation with BMI was found for the brain, the lungs, the spleen, the suprarenal glands, the thyroid, the hypophysis weight and the uterus weight.

For men, the brain, the heart, the liver and the kidneys weights were positively correlated with the body height. The correlation was non-significant for the other organs. For women, the brain, the lungs, the liver, and the kidneys were strongly correlated with body height. The correlation was weak for the heart, the suprarenal glands, the hypophysis, and the ovaries. No correlation with body height was found for the thyroid, the spleen, the pancreas weight and the uterus weight in our adult female population.

The mean and the standard deviation of the organ weight corresponding to different age groups were calculated for both sexes and are shown in Tables 8 and 9.

When there was correlation, the organ weight decreased with age except for the heart and the prostate and the weight of these two organs increased significantly with age. Another exception was the brain, which its weight increased with age under 35 Y/O and decreased after $\geqslant$35 Y/O. In general almost all organs showed slowly decrease in weights with senility except for heart and the prostate which their weights were increasing throughout the life.

## 4. Discussion

There have been no previous reports on the normal values of organ weights among Iranian autopsy patients who died from external causes. Our study population was comprised of a big sample of adult fresh cadavers which was unprecedented in our country and many other parts of the world. On the other hand, the organ weight references are only valid over a limited period of time and may vary among different populations. Thus, values of organs weight achieved by autopsy should not be compared with outdated reference tables or with data obtained from other parts of the world. In fact, the use of imprecise tables may lead to a wrong judgment on the pathological or not-pathological features of the organ, especially in forensic cases in which histology is not always performed. This implies the necessity to establish updated reference tables from appropriate autopsy material that must be without any

**Table 5**
Mean and standard deviation of organs weight (g) according to height (cm).

| Gender | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | 151 $\leqslant$ H $\leqslant$ 165 | 166 $\leqslant$ H $\leqslant$ 175 | 176 $\leqslant$ H $\leqslant$ 192 | 141 $\leqslant$ H $\leqslant$ 155 | 156 $\leqslant$ H $\leqslant$ 165 | 166 $\leqslant$ H $\leqslant$ 175 |
| Brain | 1288.8 ± 121.5 | 1320.7 ± 116.6 | 1342.0 ± 111.1 | 1161.3 ± 81.6 | 1238.3 ± 136.4 | 1275.7 ± 117.6 |
| Heart | 341.7 ± 79.5 | 363.5 ± 78.5 | 365.1 ± 69.1 | 316.6 ± 81.6 | 314.6 ± 88.6 | 299.1 ± 56.9 |
| Right lung | 534.1 ± 161.3 | 558.4 ± 175.4 | 607.9 ± 175.2 | 415.6 ± 129.1 | 453.6 ± 113.4 | 435.7 ± 58.1 |
| Left lung | 498.4 ± 135.1 | 529.5 ± 220.9 | 561.7 ± 154.2 | 400.0 ± 108.9 | 433.8 ± 97.0 | 400.1 ± 104.0 |
| Liver | 1345.6 ± 265.6 | 1491.0 ± 261.3 | 1594.0 ± 356.7 | 1390.8 ± 285.3 | 1407.3 ± 283.1 | 1321.1 ± 176.6 |
| Spleen | 153.2 ± 54.6 | 165.7 ± 64.3 | 191.5 ± 77.7 | 147.1 ± 53.6 | 149.6 ± 62.9 | 168.5 ± 109.0 |
| Pancreas | 86.5 ± 20.8 | 94.7 ± 24.9 | 100.4 ± 23.9 | 79.2 ± 18.5 | 76.9 ± 24.6 | 83.6 ± 15.1 |
| Right kidney | 138.1 ± 32.4 | 148.4 ± 56.0 | 150.4 ± 32.5 | 126.3 ± 22.6 | 128.8 ± 25.3 | 115.7 ± 8.9 |
| Left kidney | 143.6 ± 49.1 | 149.2 ± 58.6 | 153.9 ± 32.8 | 125.1 ± 22.7 | 131.6 ± 26.3 | 115.1 ± 7.7 |
| Thyroid | 18.7 ± 6.2 | 22.2 ± 6.9 | 23.7 ± 7.0 | 17.5 ± 4.0 | 17.1 ± 5.2 | 16.9 ± 4.6 |
| Right suprarenal | 10.0 ± 3.4 | 10.3 ± 4.7 | 10.0 ± 4.5 | 8.8 ± 2.5 | 10.2 ± 4.4 | 13.7 ± 5.4 |
| Left suprarenal | 10.0 ± 3.1 | 10.3 ± 4.6 | 10.4 ± 4.6 | 9.6 ± 2.7 | 10.2 ± 3.6 | 15.6 ± 7.8 |
| Hypophysis | 0.7 ± 0.3 | 0.8 ± 0.3 | 0.7 ± 0.2 | 0.5 ± 0.2 | 0.6 ± 0.2 | 0.6 ± 0.1 |
| Right testis | 23.8 ± 6.5 | 24.0 ± 5.3 | 24.7 ± 6.2 | – | – | – |
| Left testis | 25.0 ± 7.5 | 25.2 ± 6.0 | 25.6 ± 6.7 | – | – | – |
| Prostate | 36.3 ± 13.3 | 33.0 ± 13.0 | 35.2 ± 12.6 | – | – | – |
| Right ovary | – | – | – | 15.3 ± 6.7 | 17.6 ± 7.9 | 21.5 ± 6.4 |
| Left ovary | – | – | – | 15.8 ± 6.8 | 16.7 ± 6.3 | 22.1 ± 5.4 |
| Uterus | – | – | – | 60.5 ± 31.5 | 61.6 ± 29.0 | 60.0 ± 14.8 |

**Table 6**
Mean and standard deviation of organs weight (g) according to BMI (kg $m^{-2}$).

| Gender | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | 14 ⩽ BMI ⩽ 20 | 21 ⩽ BMI ⩽ 25 | 26 ⩽ BMI ⩽ 39 | 17 ⩽ BMI ⩽ 20 | 21 ⩽ BMI ⩽ 25 | 26 ⩽ BMI ⩽ 39 |
| Brain | 1316.3 ± 131.4 | 1322.6 ± 115.8 | 1329.9 ± 115.4 | 1163.7 ± 100.4 | 1239.8 ± 137.2 | 1243.9 ± 128.1 |
| Heart | 306.2 ± 54.0 | 351.0 ± 74.1 | 381.5 ± 76.8 | 210.0 ± 99.9 | 286.4 ± 60.3 | 352.6 ± 90.4 |
| Right lung | 543.8 ± 197.2 | 551.5 ± 147.8 | 587.9 ± 184.6 | 341.2 ± 120.4 | 437.4 ± 102.0 | 461.2 ± 128.0 |
| Left lung | 487.9 ± 176.7 | 528.1 ± 229.6 | 544.6 ± 162.8 | 302.2 ± 96.0 | 411.9 ± 96.0 | 442.9 ± 104.3 |
| Liver | 1379.7 ± 280.1 | 1457.0 ± 240.4 | 1619.4 ± 354.2 | 1030.2 ± 152.4 | 1298.3 ± 182.2 | 1537.0 ± 285.3 |
| Spleen | 180.7 ± 78.9 | 165.3 ± 61.9 | 180.0 ± 75.0 | 116.5 ± 40.8 | 150.6 ± 68.4 | 166.2 ± 70.5 |
| Pancreas | 89.5 ± 19.0 | 92.0 ± 24.3 | 100.8 ± 26.2 | 58.6 ± 22.6 | 71.5 ± 20.1 | 88.3 ± 23.2 |
| Right kidney | 137.9 ± 26.3 | 145.2 ± 36.5 | 155.1 ± 65.1 | 109.8 ± 18.2 | 120.1 ± 19.4 | 132.0 ± 25.4 |
| Left kidney | 143.5 ± 33.9 | 148.2 ± 36.6 | 154.8 ± 70.5 | 111.8 ± 16.7 | 121.3 ± 18.9 | 135.0 ± 28.6 |
| Thyroid | 19.5 ± 6.4 | 21.4 ± 6.7 | 23.6 ± 7.2 | 14.8 ± 3.7 | 16.6 ± 4.8 | 18.1 ± 4.9 |
| Right suprarenal | 10.4 ± 6.1 | 10.0 ± 4.2 | 10.7 ± 4.7 | 7.1 ± 4.8 | 10.6 ± 4.7 | 9.6 ± 3.8 |
| Left suprarenal | 11.3 ± 9.0 | 10.1 ± 4.0 | 10.8 ± 4.8 | 9.2 ± 3.6 | 10.3 ± 3.9 | 10.6 ± 4.6 |
| Hypophysis | 0.6 ± 0.2 | 0.8 ± 0.2 | 0.8 ± 0.2 | 0.4 ± 0.2 | 0.5 ± 0.2 | 0.6 ± 0.2 |
| Right testis | 24.0 ± 5.6 | 24.1 ± 5.5 | 25.2 ± 6.2 | – | – | – |
| Left testis | 24.3 ± 6.5 | 24.8 ± 5.8 | 26.6 ± 7.2 | – | – | – |
| Prostate | 35.3 ± 12.7 | 33.6 ± 13.1 | 34.5 ± 12.3 | – | – | – |
| Right ovary | – | – | – | 14.8 ± 7.7 | 16.6 ± 7.0 | 17.9 ± 8.0 |
| Left ovary | – | – | – | 13.2 ± 4.0 | 16.1 ± 6.0 | 17.6 ± 6.8 |
| Uterus | – | – | – | 68.5 ± 48.5 | 54. ± 29.5 | 64.8 ± 29.7 |

**Table 7**
Correlation (*P* values) of organs weights with height, BMI and age for males and females.

| Gender | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | Height | BMI | Age | Height | BMI | Age |
| Brain | 0.05 | NS | 0.01 | 0.01 | NS | 0.01 |
| Heart | 0.05 | 0.01 | 0.01 | 0.05 | 0.01 | 0.01 |
| Right lung | NS | 0.05 | NS | 0.01 | NS | NS |
| Left lung | NS | 0.05 | NS | 0.01 | NS | NS |
| Liver | 0.05 | 0.01 | NS | 0.01 | 0.01 | NS |
| Spleen | NS | NS | 0.05 | NS | NS | NS |
| Pancreas | NS | NS | NS | NS | 0.01 | NS |
| Right kidney | 0.05 | 0.05 | NS | 0.01 | 0.05 | NS |
| Left kidney | 0.05 | 0.05 | NS | 0.01 | 0.05 | NS |
| Thyroid | NS | 0.01 | NS | NS | NS | NS |
| Right Suprarenal | NS | NS | 0.05 | 0.05 | NS | NS |
| Left suprarenal | NS | NS | 0.05 | 0.05 | NS | NS |
| Hypophysis | NS | 0.01 | NS | 0.05 | NS | NS |
| Right testis | NS | 0.01 | NS | – | – | – |
| Left testis | NS | 0.01 | NS | – | – | – |
| Prostate | NS | NS | 0.01 | – | – | – |
| Right ovary | – | – | – | 0.05 | 0.05 | NS |
| Left ovary | – | – | – | 0.05 | 0.05 | NS |
| Uterus | – | – | – | NS | NS | NS |

NS: non-significant.

**Table 8**
Mean and standard deviation of organs weight (g) according to age groups in males.

| Age groups | 15–24 | 25–34 | 35–44 | 45–54 | 55–64 | 65–74 | ⩾75 |
|---|---|---|---|---|---|---|---|
| Subjects | 141 | 191 | 127 | 167 | 114 | 113 | 61 |
| Brain | 1335.7 ± 120.4 | 1350.9 ± 110.2 | 1345.5 ± 123.3 | 1324.9 ± 108.4 | 1297.2 ± 109.7 | 1292.6 ± 124.2 | 1248.1 ± 98.6 |
| Heart | 314.3 ± 64.8 | 333.8 ± 56.7 | 356.3 ± 58.5 | 369.5 ± 74.2 | 388.0 ± 78.9 | 397.2 ± 89.4 | 405.1 ± 81.9 |
| Right lung | 537.2 ± 169.9 | 572.5 ± 164.1 | 588.5 ± 168.0 | 582.3 ± 148.8 | 580.2 ± 171.0 | 553.8 ± 179.2 | 544.8 ± 128.0 |
| Left lung | 524.3 ± 176.0 | 538.2 ± 145.2 | 553.2 ± 152.1 | 545.3 ± 145.6 | 525.7 ± 121.3 | 520.9 ± 165.9 | 508.9 ± 104.3 |
| Liver | 1443.2 ± 268.7 | 1546.4 ± 320.5 | 1548.4 ± 317.5 | 1545.0 ± 293.1 | 1487.4 ± 302.4 | 1467.7 ± 275.3 | 1369.6 ± 239.9 |
| Spleen | 171.6 ± 75.3 | 177.6 ± 67.1 | 178.3 ± 70.0 | 177.4 ± 67.5 | 171.4 ± 79.7 | 159.6 ± 59.9 | 152.6 ± 58.5 |
| Pancreas | 83.5 ± 27.0 | 90.9 ± 25.9 | 96.8 ± 23.8 | 88.6 ± 23.3 | 85.8 ± 23.8 | 84.1 ± 24.4 | 80.3 ± 23.4 |
| Right kidney | 141.3 ± 29.3 | 150.2 ± 35.0 | 152.8 ± 40.8 | 149.6 ± 36.9 | 148.5 ± 37.7 | 145.8 ± 47.3 | 144.2 ± 46.8 |
| Left kidney | 143.3 ± 31.6 | 151.9 ± 33.3 | 155.5 ± 42.5 | 151.4 ± 41.8 | 150.6 ± 42.6 | 149.7 ± 49.4 | 148.0 ± 40.6 |
| Thyroid | 20.8 ± 6.8 | 22.2 ± 6.7 | 23.6 ± 7.2 | 22.7 ± 7.1 | 22.8 ± 6.8 | 21.5 ± 7.4 | 20.7 ± 7.2 |
| Right suprarenal | 9.5 ± 4.7 | 10.0 ± 4.2 | 10.4 ± 4.7 | 10.5 ± 4.3 | 10.7 ± 5.1 | 10.6 ± 4.6 | 10.9 ± 4.2 |
| Left suprarenal | 9.8 ± 4.6 | 10.2 ± 4.0 | 10.6 ± 4.9 | 10.6 ± 4.2 | 10.8 ± 5.3 | 10.4 ± 3.9 | 10.4 ± 4.0 |
| Hypophysis | 0.7 ± 0.2 | 0.8 ± 0.2 | 0.8 ± 0.2 | 0.7 ± 0.2 | 0.7 ± 0.2 | 0.7 ± 0.2 | 0.7 ± 0.2 |
| Right testis | 23.5 ± 6.5 | 24.0 ± 5.8 | 24.1 ± 4.6 | 24.7 ± 5.1 | 24.8 ± 6.9 | 24.3 ± 6.1 | 24.0 ± 6.5 |
| Left testis | 24.8 ± 7.5 | 24.8 ± 5.9 | 25.3 ± 5.3 | 26.1 ± 5.7 | 26.0 ± 7.0 | 25.8 ± 7.7 | 24.5 ± 6.7 |
| Prostate | 30.6 ± 12.1 | 30.6 ± 12.6 | 32.2 ± 10.9 | 36.4 ± 11.9 | 37.5 ± 14.7 | 39.8 ± 13.8 | 41.9 ± 14.3 |

**Table 9**
Mean and standard deviation of organs weight (g) according to age groups in females.

| Age groups | 15–24 | 25–34 | 35–44 | 45–54 | 55–64 | 65–74 | ⩾75 |
|---|---|---|---|---|---|---|---|
| Subjects | 54 | 50 | 42 | 62 | 37 | 30 | 33 |
| Brain | 1224.4 ± 149.3 | 1246.4 ± 130.2 | 1232.5 ± 108.3 | 1230.4 ± 100.1 | 1217.2 ± 104.2 | 1148.0 ± 97.2 | 1102.3 ± 72.8 |
| Heart | 267.3 ± 56.1 | 274.8 ± 42.7 | 306.3 ± 59.5 | 321.6 ± 60.8 | 351.7 ± 64.0 | 384.2 ± 85.4 | 388.1 ± 75.2 |
| Right lung | 455.9 ± 118.6 | 459.5 ± 121.1 | 460.9 ± 85.3 | 455.3 ± 102.8 | 417.7 ± 75.8 | 415.9 ± 77.3 | 414.8 ± 78.0 |
| Left lung | 414.6 ± 102.4 | 430.2 ± 111.2 | 432.5 ± 112.1 | 427.2 ± 101.6 | 397.1 ± 69.3 | 402.2 ± 48.8 | 400.9 ± 74.2 |
| Liver | 1283.8 ± 214.2 | 1326.4 ± 208.5 | 1372.0 ± 197.0 | 1492.0 ± 273.2 | 1376.4 ± 236.9 | 1367.7 ± 200.3 | 1360.6 ± 188.9 |
| Spleen | 158.2 ± 60.0 | 174.9 ± 77.1 | 175.3 ± 60.3 | 176.0 ± 62.5 | 161.4 ± 47.7 | 155.0 ± 68.7 | 154.9 ± 57.3 |
| Pancreas | 76.6 ± 23.2 | 78.0 ± 16.6 | 78.8 ± 19.5 | 84.3 ± 20.7 | 83.3 ± 14.5 | 83.1 ± 17.4 | 78.9 ± 18.4 |
| Right kidney | 133.6 ± 24.1 | 135.2 ± 15.7 | 138.8 ± 22.8 | 130.5 ± 24.5 | 126.5 ± 22.8 | 125.8 ± 19.3 | 120.2 ± 18.8 |
| Left kidney | 138.2 ± 32.3 | 144.4 ± 23.0 | 145.5 ± 25.9 | 132.6 ± 21.3 | 128.8 ± 16.5 | 128.7 ± 18.4 | 122.0 ± 20.8 |
| Thyroid | 16.3 ± 5.0 | 17.5 ± 4.2 | 18.1 ± 6.0 | 18.7 ± 6.1 | 18.8 ± 4.3 | 16.8 ± 5.4 | 15.7 ± 4.5 |
| Right suprarenal | 8.8 ± 3.7 | 9.8 ± 4.4 | 11.7 ± 4.9 | 11.0 ± 4.3 | 10.7 ± 4.7 | 10.2 ± 4.1 | 10.2 ± 4.0 |
| Left suprarenal | 8.9 ± 2.8 | 10.2 ± 4.0 | 11.9 ± 4.1 | 11.2 ± 4.3 | 11.0 ± 3.4 | 10.5 ± 3.9 | 10.3 ± 4.0 |
| Hypophysis | 0.6 ± 0.1 | 0.6 ± 0.1 | 0.8 ± 0.2 | 0.7 ± 0.2 | 0.6 ± 0.1 | 0.6 ± 0.1 | 0.6 ± 0.1 |
| Right ovary | 18.1 ± 6.2 | 19.0 ± 5.8 | 19.1 ± 6.6 | 15.7 ± 5.1 | 14.6 ± 5.5 | 14.4 ± 5.0 | 11.4 ± 6.0 |
| Left ovary | 18.3 ± 6.1 | 19.1 ± 5.9 | 19.3 ± 6.3 | 17.4 ± 5.7 | 15.0 ± 5.3 | 14.8 ± 5.5 | 11.5 ± 5.0 |
| Uterus | 56.5 ± 16.7 | 61.5 ± 20.6 | 63.4 ± 18.5 | 74.6 ± 21.9 | 59.3 ± 18.2 | 58.8 ± 16.8 | 44.1 ± 13.1 |

pathological change secondary to disease. A nonhospital population of fresh deceased persons subjected to an autopsy room would be an appropriate sample. The organs weight in such patients submitting to a wide variety of morbid accidental events can provide this type of control material because in contrast with hospital autopsies they usually have no obvious previous disease or morphological changes. Such control autopsy material is easily available in a Department of Forensic Medicine especially from cases of sudden traumatic death.[12]

Although there is some controversy, the literature review displays that the cause of death could have a major effect on the organ weight.[12,14,15] Boyd noted that the weight of an organ tends to decrease in any condition producing hypovolemic shock.[15] However, the latter observations were in disagreement with those of Myers and Segal who found no alteration in the spleen's weight in relation to cause of death or to excessive blood loss.[16] Pearl and Bacon underlined the limitation of hospital autopsy records as a suitable source of material for establishing tables of organ weight.[17] They also stated that the ideal subjects for establishing anatomical standards would be in those dying in violent accidents.[12,17]

With regards to the values for brain weight, our study found that the weight of the brain increased up to 34 years for both sexes. The brain weight was negatively correlated with age in elderly; however age-related reductions in brain weight were mild. The weight of the brain in our study was positively correlated with height for both males and females, but there was no significant correlation between the brain weight and BMI for both genders.

With regards to the values for heart weight, our study found that heart weight was strongly positively correlated with age and BMI for both sexes. The heart weight was increasing with age groups. Its cause is not clear, because we excluded all cases that likely involved in systemic hypertension which is frequently seen in the middle-aged and elderly. By microscopic examination of myocardial tissues if there was left ventricular hypertrophy and hypertensive cardiomyopathy, as well as actual measurements of heart wall thickness and weighing of the left ventricular to right ventricular muscle mass or even the presence of ancillary findings such as severely calcified atheromatous aorta, we excluded suspicious cases and ruled out the presence of systemic hypertension. Also with histology of the pulmonary artery including distal branching vessel walls, we ruled out pulmonary arterial hypertension and right ventricular hyperplasia.

The finding of a clear relationship between heart weight and BMI agrees with the studies conducted in other parts of the world.[12,16–21] When comparing our data with other studies previously published, we must consider the different characteristics of population from one study to another. For example, whether the subject indulged in physical activity, which induces cardiac hypertrophy, is usually unknown at the time of autopsy.[12]

The weight of right and left lungs of our study was positively correlated with height only for females. The range of corresponding weight values was partly wide. These strong inter-individual variations could be partially explained by the degree of terminal pulmonary edema and congestion which differs from one individual to another. On the other hand, we must remember that the organ weight per se cannot conclude pathology. For example in diagnosing pathologic lungs such as lobar pneumonia, bronchopneumonia, obstructive lung disease and emphysema, we must notice to all abnormal findings and not just weights.

The liver weight was very positively correlated with height and BMI for both sexes. The liver weight was decreased after middle age as Grandmaison and Boyd already stated.[12,15]

Our results on spleen weight confirm those of Singh et al. who found a higher spleen weight in the middle age and in male subjects.[1] They are also comparable in part with those of Grandmaison and Sprogoe-Jakobsen who did not find a correlation between the spleen weight with age and BMI.[12,22] Nevertheless, we found no correlation between the weights of the spleen with body height in this study. As mentioned earlier, while comparing our data with other studies previously published, we must consider the different characteristics of population from one study to another.

Our results about pancreas weight were related to BMI only for females. It would mean that the effect of pancreatic lipomatosis on the organ weight would be greater for women than for men because the BMI characterizes the fat rate.[13] The females in our study were on average older and bigger than the men. It has been shown that the degree of pancreatic lipomatosis was significantly correlated with age and body overweight.[23,24] So it seems these two parameters can explain the difference of correlation according to sex.

The kidneys weights were correlated to height, BMI and body weight, but not to age. These results were in concordance with those of Rasmussen et al. who found by ultrasound that the total renal volume correlated with the body weight.[25] The kidneys attained their peak weights at 35–44 years. This result was in agreement with those of Singh et al. who found a higher kidneys weight at 40–50 years.[1] As mentioned earlier, the organ weight per se can not conclude pathology. In examination of kidneys, we must consider the appearance of the renal cortical surfaces, whether still smooth, or granular, scarred and contracted, reduction in the cortical thickness, which all suggest ongoing pathology and would influence diagnosis of disease more than the weight itself.

We found a strong correlation between thyroid weight with BMI and body weight in males. There was no correlation between

the thyroid weights with all the external parameters in females. These finding were in accordance with the study of Berghout et al. who measured thyroid volume by ultrasonography in 50 healthy adults.[26] Our values showed that the weight of the average male adult thyroid was higher than that of the female. The major influence on thyroid weight is the iodine intake.[27] However, all the subjects of our study were living in a non-iodine deficient area, which could not consequently explain the difference observed between the two genders. Although, it seems immigration from an area to another area within a country can influence on the iodine intake.

The suprarenal glands and hypophysis gland weights showed some paradox correlations in both sexes. Their weights were correlated with height only for women. Whereas weights of the suprarenal glands were correlated with age, and the hypophysis weight was correlated with BMI for men. The testicles weights were correlated with BMI and mean of the left testis weight was significantly more than the right testis weight. The ovaries weights were also correlated with height and BMI. We could not explain a clear cause for these findings. The prostate weight was strongly correlated with age. This can be due to benign prostatic hypertrophy, which is more common in elderly patients. Finally the weight of the uterus showed no correlation with all the external parameters.

Almost all of the internal organs attained their peak weights at middle age, except of the heart and the prostate which their weights were increasing throughout the life.

This was the first study of organ weight in a nonhospital population of fresh deceased persons subjected to the autopsy room of the LMO which has established tables of organ weights and those might be useful for the forensic or non-forensic pathologist when performing autopsies in an Iranian or similar population. However we must remember that normal values of organ weight change with time probably under the influence of genetic factors and environmental factors such as dietary habits, daily water intake and climatic conditions.[12] The organ weight will remain a good diagnostic criterion of autopsy only if normality is accurately and regularly defined.

## Conflict of Interest

This work was supported by the Research Deputy of Iran's Legal Medicine Organization.

## Funding

This work was supported by Grant of the Research Deputy of Iran's Legal Medicine Organization.

## Ethical Approval

Written informed consent was obtained from the bereaved family of every patient prior to the autopsy examination. The ethical consideration was approved by the Ethics Committee of the Research Deputy of Iran's Legal Medicine Organization (Relevant reference number: 1/14/44232, date: 15 September 2006).

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